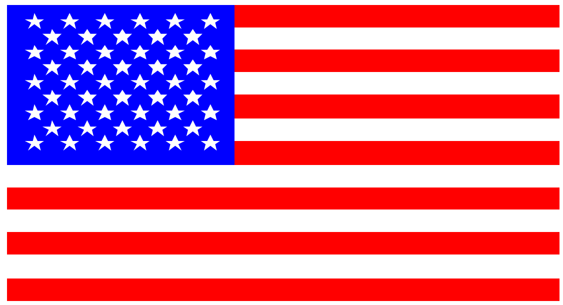
# *Wind Tunnels and Discovery*

**A Centennial WebQuest for Grades 4-6**



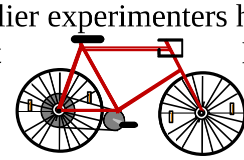
**(Flying in a box!  The Wright Brothers and the search for ground-based answers before the building full-scale airplanes.)**

## Introduction and Background:

Wilbur and Orville Wright are justly famous for their gliders and flyers.  They tested kites in 1899; experimented with a series of gliders in 1900, 1901, and 1902; and flew their first airplane, the Wright *Flyer,* at Kitty Hawk on December 17, 1903.  However, in a very real sense, *they flew in a box* first!  This flying was done on the ground in the back of their Dayton, Ohio bicycle shop in the winter of 1901 and early 1902.  In a **wind tunnel** of their own design, they answered a series of questions that had been troubling them ever since they took up the problem of flight.  Why was this testing step necessary?

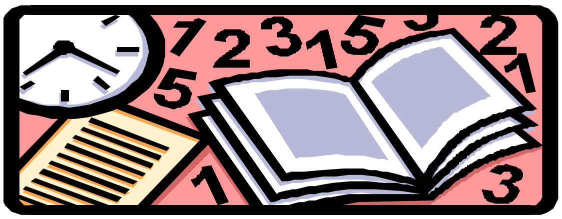
**One Thousand Years:**  Their experiments with kites in 1899 gave them confidence they could use “wing warping” as a method of twisting the wings in order to control a model glider.  Their first real manned glider in 1900 gave them some confidence that they could lift (in separate tests) sacks of sand, a small boy, and a grown man in high winds. Perhaps larger wings and a larger glider would produce more lift in a lighter wind, they assumed.  However, their experiments in Kitty Hawk in 1901 were so disappointing (poor control, not enough lift, a glider crash and injury) that Wilbur Wright told his brother Orville that man would not fly in 1000 years!  Both brothers came very close to giving up the flying “hobby” altogether in 1901, so some breakthrough in thinking must have pushed them forward.  Why was Wilbur wrong by 998 years?

**A Third Wheel:**  To answer this question, they wondered why their 1901 glider design did not produce enough lift.  They started to suspect that using the calculations of other scientists was the problem.  Perhaps these earlier experimenters had made a mistake with their numbers.  In order to be sure, the Wright Brothers decided to build their own instruments and test for the best wing shapes and sizes. Being bicycle mechanics and designers, they looked around their shop in Dayton where they kept plenty of extra bike wheels.



They mounted a spare wheel *horizontally* on the handlebars of a working bicycle so it looked something like the steering wheel of a big bus.  To this third wheel, they attached two metal plates at a 90-degree angle from each other: one was a flat plate for *drag* resistance, and the other was a 5 degree curved section shaped like a wing for *lift*. According to the lift tables of previous experimenters, these two plates should have balanced each other out, remained still and motionless in a wind. In order to create a breeze, the Brothers pedaled quickly up and down the streets of Dayton with this strange looking apparatus. Imagine what the neighbors thought! The results of all this exercise: the plates did not balance. (Determine the degree at which they did balance: Check this now. The Director of NASA will be using this question as a warm-up test of your web searching skills. http://firstflight.open.ac.uk/ Click on the Wright Brothers; then click on the movie and simulation; and then click on the Bicycle Experiments.)

The bicycle experiments were a success but only a beginning. The Wrights knew the old tables for lift and drag were wrong, but what were the right numbers? Orville and Wilbur would now create their own tables for lift and drag on a wing or ("airfoil"), tables and numbers they could rely upon for success in flying, and for safety in order to avoid further accidents. Their very lives depended upon it. They wanted a more accurate, and less exhausting experimental method than racing around their hometown on a bicycle.



**Flying in a Box:** Their next real breakthrough came with the construction of a wind tunnel. The Wrights were not the inventors of the wind tunnel, but they were the first to obtain conclusions that resulted in a successful airplane. Again, they looked around their bicycle workshop for inspiration and equipment. Their wind tunnel was built simply using plywood for the sides, a motor to turn the fan, wood strips to straighten the air, bike parts, and a glass window for observation. One is tempted to say that the Wright Brothers Wind Tunnel consisted of a small, simple fan at one end and two large, complex brains at the other!

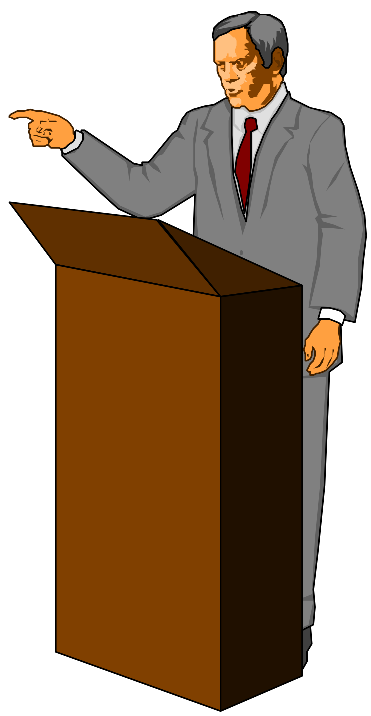
It was 6' long and 16"square. The development of the *test section* was where the engineering genius of the Wright Brothers is evident. Two balances, one for measuring lift and one for measuring drag, were designed with hacksaw blades, bicycle spokes, some wire, and an understanding of high school mathematics and geometry. Used one at a time, these balances could sit on a modern mouse pad today, or inside a foot square cube. They tested airfoil wings at various *angles of attack* to the airflow from 0 to 45 degrees. They had to be very systematic because even the slightest change could alter the delicate set-up of the balances and airflow inside the tunnel. They noticed that if they moved the furniture in the workroom the results could be affected. Why? The air moving through the fan altered the circulation in the room. Everything needed to remain constant, even the furniture.

From this set up they learned about the best length and the curve, or *camber*, for the wing to achieve the most lift; the ideal distance between the two sections of their two-level gliders; how to best shape the wingtips and the struts, etc. They tested over 200 shapes or airfoils. Many looked like modern wings but some were squares, rectangles, and ellipses. Between Thanksgiving and Christmas of 1901, they used this wind tunnel to ask many questions of nature; in return, they received answers in the form of numbers they could trust. They later said that they could hardly wait to wake up every morning during this month because it was so exciting to get answers to questions about flying that had had been a mystery for centuries and had left all others grounded. They eventually found an airfoil with a high lift and low drag ratio that they used to build their 1902 glider and obtain time enough aloft to master the art of controlled flight. In fact, this 1902 glider -- wind tunnel shaped and inspired -- was the basis for their invention claims, the grandfather patent of all future airplanes. In fact, the Wrights were able to make over 2000 glides in the 1902 machine compared with only four in the 1903 airplane. They were expert pilots because of these practice glides.

Therefore, it was in their box shaped wind tunnel that the Wrights really began to fly, where their ideas were turned into reality. It would be only two more Decembers until their first successful flight in Kitty Hawk, and not 998 years in the future.

## The Task:

The Director of NASA has to make a decision and he has asked for your help via email from headquarters. You and your group arrive in his office in Washington nervous but expectant. Excitement was in the air. He was famous for being a take-charge leader and he proved it today. The "boss" was eager to talk and started his oration before the door was closed.



***"Come in and sit down. Welcome!*** *All of the excitement about the Wright Brothers Centennial has sparked interest in innovation and discovery. By the way, did anyone come up with an answer to that email I sent out regarding the Wright Brothers and the Third Wheel? What degree of angle balanced the Third Wheel?"*

(Several teams spoke up, and the boss looked pleased.) *"Great. That tells me you have the investigative web skills to handle this job.*

*The events at Kitty Hawk in 1903 were great back then, but what about now in the 21st Century? The Chairman of the Science Committee on Capitol Hill really gave me a hard time the other day. He said, "Don't rest on your laurels. It is time for a new challenge for NASA. We need a new mission to boost the American spirit." I agree. So here is your mission.*

*Landing robots on Mars has been tried with great success. The Viking Mission in 1976 was the first. The Pathfinder yielded a lot of data in 1997 but the rover could only go so far. Those two missions are examples of our laurels! Many different "Mars Airplane" concepts and designs of the 1990's created enthusiasm and that seems to be the path for the future. The Mars Airplane will allow us to map and experience the landscape of the Red Planet … not just look down with an orbiter, or photograph rocks from a Lander with a robot camera.*

*However, we have to get the airplane to Mars in one piece! The rocket is not the problem; the problem is the landing module for the Mars Airplane, no matter what airplane design it will be.*

*To do this I need some answers. Can you help? Great. Break up into teams of four so you can generate fresh ideas and check each other's work for these Tasks.*

***Task Number #1:*** *Determine the best shape and design for a landing module so it can arrive on Mars without breaking apart.*

*Remember, the atmosphere on Mars is very thin so the Lander could crash to smithereens if we do not slow down the decent into the Martian wispy atmosphere! Test everything you can think of in a wind tunnel so we have some* ***numbers we can trust****. I seem to remember that the Wright Brothers looked at many shapes for their gliders and flyers. Do the same again. Look back at their wind tunnel work for inspiration but then answer this question: What shape will give us a lot of resistance and drag in that thin atmosphere and let the payload down gently? Show the data to support your choice.*

***Task Number #2:*** *Once the payload has been gently let down on the surface, determine the best launch angle for the Mars Airplane so it can be take-off with a catapult-style mechanism. It will have to be launched at an angle. We will not have a smooth runway to use on the rocky terrain of Mars.*

*We will have to design the plane to launch with an angle of attack that will give us the best chance of heading off in any direction and distance visible in the horizon. You will not need a wind tunnel for this question. Replicate this in the lab with simple models. We want the Mars Airplane to be able to travel down range. Is a 10-degree angle of attack the best in the Martian environment to go a short distance? Perhaps 20 degrees? What degree of launch will let the airplane travel the furthest? What degree of launch will let us hop over nearby obstacles, or do long glides over flat ground. What is the angle at which it would stall? Tell me what we have to worry about and take into account if we build such a catapult-style plane?*

*We don't have forever. How about a month? Good! Last Task:*

***Task Number #3:*** *I need a convincing report from each team on my desk in 30 days. Answer both questions to show that you understand the process of invention the way the Wrights did. The Centennial: That is all they think about these days in Congress. Why, the Wright Brothers airplanes are even on two of those new quarters!*

*I want a full and clear presentation; your leader will tell you all about the process and the format for your presentation. A strong report from <u>you</u> will greatly help <u>me</u> with Congress and the Science Committee when I go before them.*

*Boy, I wish I could do this work with you; I miss the lab and the excitement of doing research. Thanks for coming in and Good Luck!"*

## The Process:  Cooperation and Evaluation:

**1. Work in teams of four: Select Roles.**

For the sake of organization, it is best to delegate responsibilities.  Each four-person team should have a leader or **Chairperson,** a **Principal Investigator,** a **Designer,** and an **Editor.**

All four members have to make equal contributions in terms of time and effort. For example, every member of the team will write and sketch out ideas, complete data tables, support the construction of models, and speak at the final presentation to the Director of NASA.   However, individual members will have specific responsibilities:

**The Chairperson** will ensure that the team works together as a unit and completes its work on time.

**The Principal Investigator** will make sure the team is answering the key research questions posed by the Director.

**The Designer** will have overall responsibility for the "look and feel" of the poster board, demonstration, or PowerPoint presentation imparting these ideas.

**The Editor** will give unity and editorial polish to the final product.

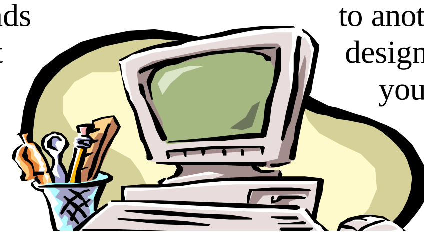
***Everyone*** will be responsible for doing his or her fair share.

**2. Establish the best approach to the problem.**

Think through each step so you will be able to deliver the best final product.  Be sure that you understand the Introduction and Background section.  Should you jump right in, or should you make a plan?  Map out your strategy.  This is where the Chairperson is crucial.

**3. Start you web research and build models as needed.**

The *Student Resources Page* has several links for you to consider.  As with all Internet searching one link leads to another and you may discover items this Web Quest designer never noticed. Select the sites that will help you find direct proof so you can come up with answers you can



trust. The Principal Investigator should always keep the big picture in mind: *Determine the best shape and design for a landing module so it can arrive on Mars without breaking apart. Determine the best launch angle for the Mars Airplane so it can be launched for different missions with a catapult-style mechanism.*

**4. Plan the presentation.**

A "beginners mistake" common among teams is to wait until the last minute to actually put together the final presentation. Do not wait until it is too late and you are rushed. The Designer and Editor should look ahead, illustrate, and express a clear and concise format for delivering your conclusions.

**5. The Final Deliverable: Show, don't tell!**

The Director is looking for proof of web-based research and hands-on experiments that come from that research. Show your results in an interesting and organized fashion.

## Student Resources:

The resources below will be the most help in your Wright Brothers Wind Tunnel Web Quest. Check out each one. However, this list is not complete, no more than the Internet is ever finished or complete. If you use a favorite search engine and carefully define your search, you may locate new resources on the topic. If so, share them with your teacher. At times, your teacher will call you together in teams for discussions, or perhaps just meet with the Chairperson of the Principal Investigators. Your teacher will also help you construct the Wind Tunnel and a Launch Ramp. Good luck on your task!

### Wind Tunnels:

**A Very Simple *Open Air* Wind Tunnel:** Is it too simple, or just right for our effort?
http://www.pbs.org/saf/1109/teaching/teaching2.htm

**A *Vertical* Wind Tunnel:** This is for fun.
http://www.primeline.com/%7Ehighwind/whp_home.html

**NASA Observatorium "Teacher's Guide" on Wind Tunnels**: This is intended for high school age students, but the wind tunnel described might be too simple for our project. What do you think?
http://observe.arc.nasa.gov/nasa/education/teach_guide/tunnel.html#act

**The *Baals* Wind Tunnel:** Nice, but might it be too complicated for our purpose? You decide.
http://ldaps.arc.nasa.gov/Curriculum/tunnel.html

***Foil Sim II*:** This is a computerized simulation for looking at airfoils where you can control the input conditions. It is very advanced and is included here for the very ambitious researcher.
http://www.lerc.nasa.gov/WWW/K-12/airplane/foil2.html

***The Measurement of All Things: Tools of the Aeronautics Trade*** >> This is from the **NASA Connect** Series. Might it be what we are looking for to build a working classroom wind tunnel at low cost? Can you fly in this box? http://connect.larc.nasa.gov/pdf/measure.tools.guides.pdf

## The Mars Airplane:

***Mars Flyer :*** This is necessary read and a great overview on the topic. http://www.pbs.org/saf/1109/features/mars.htm

***Mars Flyer:*** More on this interesting topic. http://www.pbs.org/saf/1109/features/mars3.htm

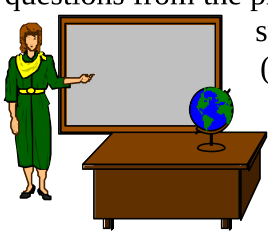
***Helios:*** Is this the best way to fly around Mars? How would we land and launch a plane like this? http://www.aerovironment.com/news/news-archive/nasahi.html

***Testing Orville:*** Didn't Orville Wright die over 50 years ago? What could this site have to do with Orville and the Mars airplane quest? Search it and find out. Print it out for ease of reading. http://amesnews.arc.nasa.gov/astrogram/2001_astrograms/9401Astrogram.pdf

***Know All the Angles*** >> This is from **NASA Quest** and looks at lift questions. It also involves the Wrights since these questions were important to them. Really look over this section. http://quest.arc.nasa.gov/aero/wright/teachers/angles/

# Teacher and Parent Resources:

A WebQuest is an activity that can vary in scope and scale. What makes it different from regular curricular resources is that most of the information needed to answer the questions from the prompt can be found through online resources linked above. We



suggest having the students work in teams of no more than four (Chairperson, Principal Investigator, Designer, and Editor) to allow for concentrated but distributed responsibility for the task. The classroom ground rules you have established for online research, working in teams, doing homework, fair sharing, and reporting out to the larger class should obtain for this endeavor also.

These activities are intended for students in the 4th to 6th grade band. It can be done in schools or with home-schooled students.

- **The Director:** A local scientist, the principal, a science coordinator, or colleague might like to serve as the *Director of NASA.* He or she could use the text above as a sort of script, present the task, this WebQuest, to the class, and then return in a month to hear and evaluate the results. The Director could send email on occasion to each Chairperson to give advice and encouragement, or nag about deadlines! After all, he is the boss. Perhaps this person of generous volunteer spirit could make an appearance with a few friends (NASA technicians with lab coats) to help construct the wind tunnel, and the launch ramp.

- **Flying in a Box:** The instructor should explore the links listed for the student in advance of giving this assignment, and should have established sufficient prior knowledge with the children so as to be confident in their ability to tackle this web quest. Two links are fundamental and indispensable for the teacher of this activity. This is the essential link relative to the lift questions: http://connect.larc.nasa.gov/pdf/measure.tools.guides.pdf
On the fourth to fifth page, depending on PDF format, it provides instructions for building a superb vertical wind tunnel ideal for this age group. This is a *highly suggested* hands-on activity for this web quest and investigation.

- **Lift and Launch:** This is the essential link relative to the lift questions; please read it and print it out.
http://quest.arc.nasa.gov/aero/wright/teachers/angles/lift_and_angle_of_attack.html It provides instructions for constructing a wonderful "Lift and Launch Angle" activity ideal for this age group. This is also a *highly suggested* hands-on activity for this web quest and investigation.

Thank you considering this NASA Wright Brothers Centennial WebQuest, and thank you for all that you do for your students everyday of the school year.

## Standards

### The National Science Education Standards for Grades 4-6.

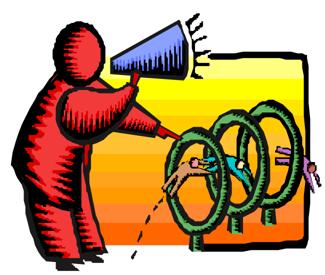
**http://books.nap.edu/html/nses/html/**

**Content Standard A – *Science as Inquiry***

**Content Standard G – *History and Nature of Science***

### The National Council of Teachers of Mathematics Standards for Grades 3 - 5.

***http://standards-e.nctm.org/document/chapter5/meas.htm***



***Measurement:***

**Understand measurable attributes of objects and the units, systems, and processes of measurement**

**Apply appropriate techniques, tools, and formulas to determine measurements**

***Data Analysis:***

**Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them**

*Representation:*
**Instructional programs from prekindergarten through grade 12 should enable all students to—create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; use representations to model and interpret physical, social, and mathematical phenomena.**

## National Technology Standards

**http://cnets.iste.org/**

**Standard 4:** ***Students will develop an understanding of the cultural, social, economic, and political effects of technology.***

**Standard 5:** ***Students will develop an understanding of the effects of technology on the environment.***

**Standard 18:** ***Students will develop an understanding of and be able to select and use transportation technologies.***

# Standards for All Subject Areas and in All States: A Master Listing by NASA

**http://education.nasa.gov/k12.html**